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PATENT SPECIFICATION

(11) 1 459 647

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(21) Application No. 29919/74 (22) Filed 5 July 1974
(31) Convention Application No. 376499 (32) Filed 5 July 1973 in (19)
(33) United States of America (US)
(44) Complete Specification published 22 Dec. 1976
(51) INT CL[2] H01G 9/04//C25D 11/26
(52) Index at acceptance
H1M 3B1 3B2C 3B2D 3B3H 3B4B 3B4F 3C3 3E3 3K
C7B 13 15X 16A 16X 2F

(54) IMPROVEMENTS IN AND RELATING TO ELECTRICAL CAPACITORS

(71) We, SPRAGUE ELECTRIC COMPANY, a Corporation of Massachusetts, of North Adams, Massachusetts, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be substantially described in and by the following statement:—

This invention relates to solid electrolytic capacitors. The invention concerns improved methods of making such capacitors, and also to improved forms of capacitors.

The invention includes a method of manufacturing a solid electrolytic capacitor including the steps of preparing a mixture including finely divided valve metal, said mixture exhibiting substantially no flow when in a horizontal thick film and under conditions of zero agitation, screen printing a layer of said mixture on a substrate having a surface of the valve metal to produce a layer having an outer surface reflecting the pattern of said screen, and sintering said screened layer to produce a porous valve metal sinter bonded to said valve metal surface.

The invention also includes a method of manufacturing a solid electrolytic capacitor comprising the steps of preparing a mixture of finely divided valve metal powder and a binder to produce an ink exhibiting substantially no flow when in a horizontal thick film and under conditions of zero agitation, screen printing one layer or a succession of layers of said mixture on a substrate having a surface of the valve metal to produce a layer or a composite layer having an outer surface reflecting the pattern of said screen, said valve metal surface providing an anode connection for said capacitor, heating each said layer after screening to cause said layer to solidify, and sintering the screened layer or composite layer at between 1550°C and 2000°C, thereby to produce a porous valve metal sinter bonded to said valve metal surface.

The invention also comprises an electrode structure for an electrolytic device comprising a substrate having at least one surface made of a valve metal, a porous layer of said valve metal printed on and sinter bonded to the said surface, said layer having an outer surface reflecting the pattern of the screen used to print the porous layer, and a valve metal oxide film over the exposed surface of said valve metal.

The invention also comprises a solid electrolytic capacitor comprising a substrate having at least one surface of a valve metal, said valve metal surface serving as the anode connection of said capacitor, a porous layer of said valve metal printed on and sinter bonded to said valve metal surface, said layer having an outer surface reflecting the pattern of the printing screen used to print the porous layer, a valve metal oxide film formed over the exposed surfaces of said valve metal surface and said valve metal layer, a solid manganese dioxide electrolyte permeating said porous valve metal layer and in contact with said valve metal oxide film, and counterelectrode over said manganese dioxide electrolyte, said counterelectrode serving as the cathode connection of said capacitor.

The invention can be applied to capacitors for use in planar mounting and hybrid integrated circuit systems, and provides in one form, a highly miniaturized solid tantalum capacitor, and in another form a multiple solid tantalum capacitor assembly having a high packing density. The invention makes possible the manufacture of solid tantalum capacitors requiring only low cost tooling, thus reducing the cost of manufacturing.

Features and advantages of the invention will also appear from the following description of embodiments thereof, given by way of example and the accompanying drawings, in which:

Figure 1 shows a side elevational view of

a tantalum substrate having an assembly of layers of tantalum deposited thereon;

Figure 2 shows a plan view of the assembly of Figure 1;

Figure 3 is a plan view of a tantalum substrate having sixteen tantalum capacitor elements formed thereon;

Figure 4 shows a magnified diagrammatic cross-sectional view of a capacitor element;

Figure 5 is a plan view of a polarised capacitor cut from an assembly of a large number of similar capacitors, and having lead wires attached;

Figure 6a is a plan view of a non-polarised capacitor of this invention;

Figure 6b is a sectional view showing the capacitor of Figure 6a mounted in flip-chip fashion on a printed circuit board or on an integrated circuit;

Figure 6c is a plan view of the capacitor of Figure 6a with lead tabs attached;

Figure 7a is a plan view of a polarised capacitor;

Figure 7b is a sectional view showing the capacitor of Figure 7a mounted in flip-chip fashion;

Figure 7c is a plan view of the capacitor of Figure 7a with lead tabs attached;

Figure 8 is the sectional view of a DIL package incorporating the capacitor of Figure 7c, taken on the line 8—8 of Figure 7c;

Figure 9 is a diagrammatic plan view of a package including a plurality of capacitors with a common anode connection;

Figure 10 is a sectional view of the package of Figure 9 taken on the line 10—10;

Figure 11 is a diagrammatic plan view of a package including a plurality of capacitors with a common cathode, and

Figure 12 is a sectional view of the package of Figure 11 taken on the line 12—12 of Figure 11.

In general the solid electrolytic capacitors to be described are made by screen printing one or more layers of a mixture of valve metal powder in a liquid binder on the surface of a substrate of the same valve metal. The printed composite layer is sintered, resulting in a porous valve metal layer sinter bonded to the face of the valve metal substrate. The sintered pad has a rough surface exhibiting a pattern reflecting that of the screen mesh. A valve metal oxide film is formed, a solid electrolyte of MnO_2 is applied over the film, and a counterelectrode is applied over the MnO_2.

Many capacitors can be made simultaneously on one substrate and subsequently cut apart into sections containing one or more capacitors each. Screen printing is advantageously employed in the steps of masking between capacitor elements and in application of the counter-electrode. Since the screens present the major tooling requirements for the manufacturing process, a comparatively low cost tooling system, and a unified and comparatively low cost production facility are afforded.

In manufacture, one or more thick film pads of a thick ink containing tantalum powder are screen printed upon a tantalum sheet. A suitable screen printing ink is prepared by mixing finely divided tantalum powder with a binder, and if necessary a thinner or solvent, so that the screened material forms a thick horizontal pad of the ink with substantially no levelling or flow under static conditions, that is, in conditions of zero agitation.

Figure 1 is a side view and Figure 2 is a plan view of tantalum substrate 10 with thick pads 11 deposited thereon. The screen is made with masked portions and ink passes through certain portions only of the screen so as to form the pads 11. The sixteen pads shown are merely by way of example, since one pad or several thousand pads can be screen printed in this way on a single substrate.

Each pad 11 is shown in Figure 2 as having a rough surface 12, which corresponds to the pattern of the screen used. This surface roughness is advantageous in the manufacture of the capacitors, as will be shown. The lack of flow of the printed pads permits the printing of wet ink pads whose separation and spacing is retained, which permits high density printing of small pads that otherwise might run together, or preclude the use of the spaces between adjacent pads for other purposes.

In the preferred method, the ink is screen printed on a tantalum substrate, providing a thin layer of ink of several mils thickness, such as 0.004 inch. A blast of hot air is directed for a few seconds on to the top surface of the substrate and the ink layer, causing volatile materials in the ink to evaporate, and causing the layer to solidify. A second layer of ink is printed on top of the first, in register with the first layer. Heat is again applied to solidify the second layer. The printing and heating steps may be repeated as many times as necessary to achieve an aggregate layer of the solidified tantalum mixture of the desired thickness, though one layer may be sufficient for some purposes.

The coated substrate is placed in a vacuum furnace and sintered at a temperature between 1550°C and 2000°C. During this exposure to high temperature under vaccum conditions the binder of the tantalum ink is decomposed and drawn off and the tantalum particles become bonded

to one another and to the underlying tantalum substrate. The result is a highly porous layer or pad of tantalum that is sinter bonded to the tantalum substrate.

Contact to the substrate is made by means of a tantalum lead wire or tab extending from the substrate, and the substrate and porous tantalum layer are anodised by any well known method to produce a tantalum oxide film over all tantalum surfaces. The tantalum oxide becomes the capacitor dielectric.

After rinsing and removing the anodising electrolyte, a barrier coating, consisting for example of silicone varnish or Teflon material (Registered Trade Mark), is applied over the oxidised tantalum surface in regions between the tantalum pads. A suitable material is one sold in the U.S.A. by E.I. DuPont Company, such as DuPont Teflon (Registered Trade Mark) Type 851-204, though many other fluorocarbon materials are suitable.

Figure 3 shows the tantalum substrate 30 with barrier coating paths, such as 33 and 34, between the pads 31. The barrier coating is preferably applied by screen printing, followed by airing. When the capacitor elements are subsequently separated by cutting the assembly, the barrier coating serves primarily to prevent short circuits between the tantalum face anode connection and the solid manganese dioxide electrolyte that is next applied to the porous tantalum pads. The manganous nitrate which can be used, and which becomes converted to manganese dioxide, does not wet and does not adhere to the barrier coating. Other methods can be used for applying the coating, including dispensing the wet coating material by means of a pen, for example pen type AR21 made in the U.S.A. by the Wood-Regan Instrument Company. In this method of coating, all parallel paths may be drawn simultaneously using a number of such pen instruments that are mechanically ganged.

The substrate is held by one edge and immersed in an aqueous solution of a manganous salt, preferably manganous nitrate. Upon removal, the manganous nitrate drains away easily from the smooth surfaces while remaining in substantial thickness over the rough surfaces of the porous tantalum pads. The substrate is placed in an oven having a temperature of from 250°C to 450°C, causing the manganous nitrate first to permeate the porous tantalum pads, and then to pyrolise and become converted to manganese dioxide (MnO_2). The MnO_2 forms the cathode electrode. It is conventional practice to reform the tantalum oxide film at this point.

Colloidal graphite is deposited over the manganese dioxide, the graphite coating can be applied by selectively screen printing over the pads, and heating the coating to cause it to solidify. A silver paste, made of silver particles held in an acrylic binder (such as DuPont Type 4817) is applied over the graphite by selective screen printing, or alternatively by brushing, and is then heated and cured. If desired, the substrate at this stage can be dipped in molten 60/40 tin-lead solder, having about 2% silver content, at about 200°C. Alternatively, a solder paste can be applied to the silver by screen printing and reflowing the solder at a temperature of 200°C. This graphite-silver-solder system is but one of many effective counter-electrodes that may be applied over the solid electrolyte to form the means for making connection to the capacitor element. For example a silicone resin loaded with silver particles may be substituted for the acrylic silver paste aforementioned. The particular solder alloy used may be chosen to accommodate a variety of needs including high temperature, such as 400°C, solder reflow attachment of capacitor cathodes to an integrated circuit substrate.

The above manufacturing process steps described are such that definition can be obtained by screen printing while other steps involve dipping or submersing. Thus only low cost tooling is required to provide multiple or single capacitor sections of wide variety in size, physical arrangement and ratings.

When the counterelectrode has been applied each tantalum pad has been developed and transformed into a solid tantalum capacitor element, all such elements having a common anode connection at the tantalum face of the substrate.

The capacitor elements thus formed can now be separated into sections each including an individual capacitor or a group of capacitors, by cutting or otherwise separating the tantalum substrate in the spaces between the pads where the barrier coating is located. Examples of cuts are shown by the dotted lines 36 and 37 in Figure 3. The cutting may be accomplished by any of several well known semiconductor wafer dicing means. For example the abrasive wire saw described in U.S. Specification No. 3,435,815 has proved effective, and laser cutting is also appropriate. Separating the sections by cutting involves little waste of the expensive tantalum material and is particularly appropriate for the small element dimensions and close spacing used with multiple capacitors.

Figure 4 is an enlarged diagrammatic

cross-sectional detail view of a single tantalum capacitor element though the details are the same for the capacitor elements of a multiple assembly. A ceramic substrate 40 has a tantalum film 41 deposited on a top surface. A tantalum pad 42 is sinter bonded to the tantalum surface on the substrate 40. A tantalum oxide film 43 is shown over all exposed regions of the tantalum face 41 and the porous tantalum pad 43, including all its interstitial surfaces. Barrier coating 44 covers a portion of the tantalum oxide that is over the tantalum face of the substrate 40. A solid manganese dioxide electrolyte 45 covers the tantalum oxide film 43 except that covered by the barrier coating 44. On the MnO_2 electrolyte a counterelectrode is built of successive layers of graphite 46, silver 47, and solder 48.

Figure 5 shows a single solid tantalum capacitor cut from a multiple capacitor substrate such as that shown in Figure 3. A cathode lead wire 54 is attached to the counterelectrode 51 of the capacitor and an anode wire lead 55 is attached to the tantalum sheet 50. The leads can be connected before the individual capacitor elements have been separated from the multiple substrate. The capacitor of Figure 5 is especially suitable for mounting and connection in a hybrid integrated circuit when thermocompression bonding can be used to attach the lead wires 54 and 55 between the capacitor and the circuit.

Figures 6a, b, c show a section of two capacitors on a common tantalum substrate 60. By making contact to the counterelectrodes 61 and 63 on capacitor pads 62 and 64, respectively, a single leadless non-polarised capacitor, that is, a capacitor not limited to use with unidirectional applied voltage, is obtained. The non-polarised capacitor of Figure 6a can be mounted in an inverted position, as shown in Figure 6b without leads in the manner of a so called flip-chip, for example the counterelectrode is given an outer coating of solder so that the substrate 60 can be inverted with the solder coating facing solderable lands 67 and 68 on a hydrid integrated circuit 69; a joint is then effected by applying heat and reflowing the solder. Alternatively, metal tabs 65 and 66 as shown in Figure 6c can be attached to the counterelectrodes 61 and 63, respectively, thereby providing a non-polarised capacitor with leads. Lead attachment can be effected by reflow soldering, or other suitable means.

In Figure 7a is shown a single capacitor element 71 on a tantalum substrate 70. A metal bar 73 preferably of nickel or Kovar (Registered Trade Mark), a trade name for an expansion alloy made by the Westinghouse Electric Corp., is spot or tack welded to the substrate 70 after application of counterelectrode materials. Such a weld may be made through the barrier layer and tantalum oxide film by an energy discharge weld method. The bar 73 is advantageously about the same height as the capacitor body 72, so that when inverted the capacitor is mounted evenly, as shown in Figure 7b, on a circuit member 79, making connection to conductive lands 77 and 78 and providing a leadless, flip-chip, polarised capacitor. Alternatively, as shown in Figure 7c, metal tab leads 75 and 76 can be attached to the counterelectrode 71 and to the bar 73 respectively, to provide connection leads to the capacitor.

It is seen that both single or multiple capacitors such as those of Figures 6 and 7, are suitable for incorporation in a moulded component package, such as the conventional dual in-line package (DIL), employed for printed wire board mounting.

Figure 8 is a transverse cross-sectional view of such a package, in which a plastic material 80 encompasses the body of the capacitor of Figure 7 and a portion of the tab leads. The tab leads 75 and 76 can be formed as part of a conventional lead frame, to which the capacitors, and, it may be, other components are welded, soldered, or otherwise connected prior to moulding.

Other dual in-line package arrangements can be adopted with the capacitors described in which the capacitors are connected by means with either a common positive terminal or a common negative terminal. In Figure 9 is shown a package wherein twelve discrete capacitors 91 are contacted by two metal tab leads 93, which are connected to the tantalum face 90 of a substrate that is common to all of the tantalum pads, thereby producing an array of capacitors with common positive polarity. A metal tab lead 92 is attached to the counterelectrode of each capacitor, thus providing individual negative connections to the capacitors. Figure 10 shows a cross-sectional view taken on the line 10—10 of Figure 9, showing the encapsulation in a plastic insulating material 94.

Although the above described capacitors, and the methods for making them, employ a tantalum substrate, it should be noted that other substrate materials can be used. For example 99.5% pure alumina can be used, the substrate having a thin film of tantalum sputtered on to one face of it. Alumina of this high purity can withstand sintering temperatures of about 1600°C without adversely affecting the quality of the tantalum anode. When an alumina substrate is used for the manufacture of the capacitors, the standard

method of scribing and breaking is suitable for separating the capacitor sections.

To produce a DIL package including a plurality of capacitors with a common negative polarity, an alumina substrate of the kind described above can be employed. After the capacitors have been made as described the capacitors can be isolated from each other but retained on the same substrate, by vaporising the tantalum film between the capacitors. For instance, a laser beam may be used to vaporise the tantalum without cutting through the ceramic substrate. Figure 11 shows a DIL system of this description. The tantalum film 110 deposited on the ceramic substrate 115, has been locally vaporised and removed to isolate the individual capacitors 111, individual connection, to the points of positive potential is made by individual metal tab leads 112, and common connection to the negative counterelectrodes is made by the metal part 113 which is fixed by soldering or other means to each capacitor body 111. The whole is encapsulated by a plastic material 114 and is shown in the cross-sectional view of Figure 12 taken on the line 12—12 of Figure 11.

The small dimensions and close spacing required of the capacitors for DIL packages can be readily achieved and the generally planar geometry arrangement of the capacitor assembly is also suitable for such packages, but other combinations and variations beyond can be used for DIL and similar packages.

In a practical example, multiple capacitor plates designed for direct assembly in a standard sixteen leads DIL package were made on a tantalum substrate 0.005 inch thick and measuring 0.188 inch by 0.750 inch. An ink was prepared consisting of a homogeneous mixture of 85% by weight tantalum powder of particle sizes ranging from 3 to 10 microns, 2-1/2% of a binder such as Elvacite comprising a polyisobutyl methacrylate (Elvacite is a Registered Trade Mark of E.I. DuPont Co.) and 12-1/2% of a solvent being a glycol butyl ether (n-Butyl Cellosolve (Registered Trade Mark) supplied by Union Carbide Co.).

Valve metals other than tantalum, such as aluminium or titanium are also suitable provided the substrate has a surface of the same valve metal.

A 200 mesh screen of 0.0016 inch diameter stainless steel wires and having a 0.001 inch thick transfer emulsion mask was employed. A hot air gun was used to solidify each screened layer before the next layer was screened. The rough surface of the resulting composite layer was estimated to reduce the necessary steps of manganous nitrate application and pyrolysis by at least 20% compared with that required for a smooth surface.In addition, the adherence of the counterelectrode materials was notably improved. The resulting tantalum pads of each capacitor element were about 0.020 inch thick, with lateral dimensions of 0.088 inch by 0.067 inch, and with about 0.020 inch spaces between pads. The fourteen capacitor elements on one plate were each 4.7 microfarads rated at 6 volts. On another similar plate they were each 1.2 microfarads rated at 20 volts. With respect to the anodizing voltage, the resulting microfarad-volt product of each capacitor element was calculated to be about 70 μfd-V.

From these data it can be shown that the capacitors made as described had a figure of merit of 600,000 μfd-volts per cubic inch, which is directly comparable to the figure of merit normally obtained by a conventional method comprised of compacting tantalum powder in a mould and subsequently forming the tantalum oxide dielectric and the counterelectrode. This is a surprisingly high figure and is thought to be due to the fact that by screen printing, tantalum ink compaction is brought about by the pressure of the screening squeegee and by pressure of the downward deflected screen itself, causing the density of the tantalum powder to increase under the screen leaving a layer of purified solvent on top which is driven off by the subsequent heating. The resulting rough surface of the sintered tantalum pad, which roughness reflects the pattern of the screen, lends support to the theory. Other factors may however be responsible for these results.

WHAT WE CLAIM IS:—

1. A method of manufacturing a solid electrolytic capacitor including the steps of preparing a mixture including finely divided valve metal, said mixture exhibiting substantially no flow when in a horizontal thick film and under conditions of zero agitation, screen printing a layer of said mixture on a substrate having a surface of the valve metal to produce a layer having an outer surface reflecting the pattern of said screen, and sintering said screened layer to produce porous valve metal sinter bonded to said valve metal surface.

2. A method of manufacturing a solid electrolytic capacitor comprising the steps of preparing a mixture of finely divided valve metal powder and a binder to produce an ink exhibiting substantially no flow when in a horizontal thick film and under conditions of zero agitation, screen printing one layer, or a succession of layers of said mixture, on a substrate having a

surface of the valve metal to produce a layer or a composite layer having an outer surface reflecting the pattern of said screen, said valve metal surface providing an anode connection for said capacitor, heating each said layer after screening to cause said layer to solidify, and sintering the screened layer or composite layer at between 1550°C and 2000°C, thereby to produce a porous valve metal layer sinter bonded to said valve metal surface.

3. A method according to claim 1 or claim 2 and including the steps of forming by an electrolytic process a valve metal oxide film over exposed regions of the valve metal and providing a solid electrolyte in contact with said film.

4. A method according to claim 3, and including the steps of applying to said valve metal having an oxide film over it an aqueous solution of manganous salt, heating said salt solution to cause said salt to permeate said porous pad and to transform said salt into manganese dioxide by pyrolysis.

5. A method according to claim 4, wherein said aqueous solution is applied by dipping.

6. A method according to any of the preceding claims, and comprising applying a conductive counter electrode over said layer or layers to form a cathode connection.

7. A method according to any of the preceding claims, and comprising preparing said mixture by homogeneously combining finely divided valve metal powder, having particle sizes from 3 to 10 microns, in a binder of polyisobutyl methacrylate and a vehicle of a glycol butyl ether, in the proportions by weight of substantially 85%, 2-1/2% and 12-1/2%, respectively.

8. A method according to claim 6, wherein said counterelectrode is provided at least in part by screen printing.

9. A method according to any of claims 1 to 7, wherein said screen is partially masked, and said mixture is thereby screened on to said surface as a plurality of individual areas.

10. A method according to claim 9, wherein the processing of the said plurality of areas is continued to sintering and forming without severing said areas.

11. A method according to any of the preceding claims, wherein successive layers of valve metal powder are simultaneously screen printed on areas on said valve metal face.

12. A method according to any of the preceding claims, and including the step of depositing a barrier coating on parts of said oxidised valve metal face between areas of the mixture layer.

13. A method according to claim 12, wherein said barrier coating is deposited by screen printing.

14. A method according to claim 12, wherein said barrier coating is deposited by a process of wet drawing.

15. A method according to any of the preceding claims, and including the step of removing from said substrate, between areas of said mixture layer, the valve metal film.

16. A method according to claim 15, wherein said valve metal film is removed by use of a laser beam.

17. A method according to any preceding claim, wherein said substrate comprises a plurality of areas on which said mixture layer is deposited, and comprising the step of physically separating sections of said substrate each with one or more such areas.

18. A method according to claim 17, wherein said substrate is divided by a scribe and break method.

19. A method according to claim 17, wherein said substrate is divided by a moving abrasive wire.

20. A method according to any of the preceding claims, comprising the step of sputtering a coating of said valve metal on to a ceramic body, to form said substrate.

21. A method according to any of the preceding claims, wherein said valve metal is tantalum.

22. A method according to claim 6, wherein said counterelectrode is provided by applying a first coating of graphite, a second coating of conductive silver paste and third coating of solder.

23. A method according to claim 6 or 22, wherein said counterelectrode is provided, at least in part, by screen printing.

24. A method according to claim 6, 22 or 23, and comprising the step of connecting at least one wire lead to said valve metal substrate and one wire lead to said counterelectrode or each counterelectrode.

25. A method of making an electrode for an electrolytic device, substantially as described with reference to the accompanying drawings.

26. An electrode structure for an electrolytic device comprising a substrate having at least one surface made of a valve metal, a porous layer of said valve metal printed in and sinter bonded to the said surface, said layer having an outer surface reflecting the pattern of the screen used to print the porous layer, a valve metal oxide film over the exposed surface of said valve metal.

27. A structure according to claim 26, and comprising a solid manganese dioxide electrolyte permeating said layer and in contact with said film.

28. A structure according to claim 27,

and comprising a counterelectrode over said electrolyte.

29. A solid electrolytic capacitor comprising a substrate having at least one surface of a valve metal, said valve metal surface serving as the anode connection of said capacitor, a porous layer of said valve metal printed in and sinter bonded to said valve metal surface, said layer having an outer surface reflecting the pattern of the printing screen used to print the porous layer, a valve metal oxide film formed over the exposed surfaces of said valve metal surface and said valve metal layer, a solid manganese dioxide electrolyte permeating said porous valve metal layer and in contact with said valve metal oxide film, and a counterelectrode over said manganese dioxide electrolye, said counterelectrode serving as the cathode connection of said capacitor.

30. A capacitor according to claim 29, wherein said substrate is formed of a sheet of said valve metal.

31. A capacitor according to claim 29, wherein said substrate is formed of a ceramic base and said valve metal surface consists of a film of valve metal deposited on said ceramic substrate.

32. A capacitor according to claim 30 or 31, wherein said valve metal is tantalum.

33. A capacitor according to any of claims 29 to 32 and comprising a first metal lead attached to said valve metal face and a second metal lead attached to said counterelectrode.

34. A capacitor according to claim 33, wherein said first and second leads are flat metal tabs that extend in opposite directions.

35. A capacitor according to any of claims 29 to 34, comprising an insulating material encompassing the body of said capacitor.

36. A capacitor according to claims 34 and 35, wherein said insulating material encompasses a portion of said tabs.

37. A capacitor according to any of claims 29 to 35 and comprising a metal bar welded to said valve metal face, said bar having approximately the same thickness as said layer, whereby said bar is adapted for use as an anode connection and said capacitor is adapted for connection to a flat integrated circuit substrate by said counterelectrode and said anode connection.

38. A capacitor according to claim 36, and comprising a first flat metal tab connected to said cathode bar and a second metal tab connected to said anode counterelectrode, said first and second tabs lying in substantially the same plane and extending from said capacitor in opposite directions.

39. A capacitor according to claim 29, wherein said layer presents discrete areas of porous valve metal each sinter bonded to a separated portion of said valve metal face, each area having a valve metal oxide film, a solid manganese dioxide electrolyte, and a counterelectrode, whereby a plurality of solid electrolyte valve metal capacitor elements are presented on the same substrate.

40. A capacitor according to claim 39, and comprising a metal part, said counterelectrodes of said plurality of said capacitor elements being connected to said metal part, such that said metal part serves as a common cathode connection for all said capacitor elements.

41. A capacitor according to claim 29, wherein said layer presents discrete areas of valve metal sinter bonded to said valve metal face, each area having a valve metal oxide film, a solid manganese dioxide electrolyte, and a counterelectrode, whereby a plurality of solid electrolyte valve metal capacitor elements are formed on the same substrate.

42. A capacitor according to claim 41, further comprising a lead wire attached to said valve metal face, serving as a common anode lead wire to said plurality of capacitor elements, and a plurality of cathode lead wires, each said cathode wire being attached to one said counterelectrode of each said capacitor.

43. A capacitor according to claim 41, wherein at least one capacitor comprises two said capacitor elements, in effect to provide a single non-polarised solid electrolytic capacitor.

44. A capacitor according to claim 43, wherein connections at said counterelectrodes are made by flat metal tabs that lie in the same plane and extend from said non-polarised capacitor in opposite directions.

45. A capacitor according to claim 44, further comprising a housing of an insulating compound encompassing the body of said non-polarised capacitor and a portion of said tabs.

46. An electrode structure or capacitor substantially as described with reference to the accompanying drawings.

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Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1976.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1459647 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig. 1.

Fig. 2.

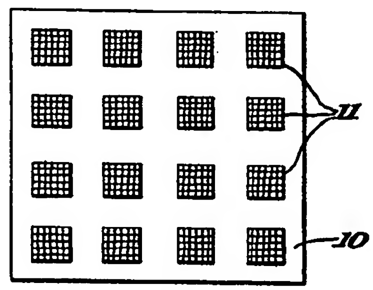


Fig. 3.

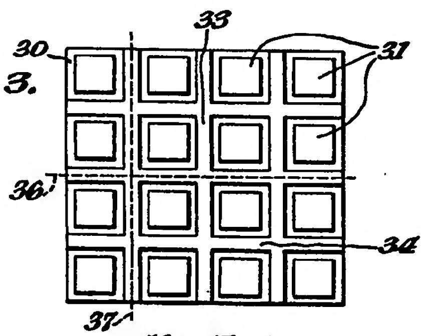


Fig. 4.

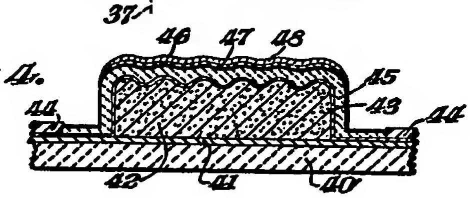


Fig.5.

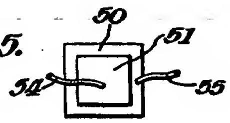


Fig.6a.

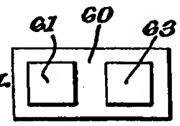


Fig.6b.

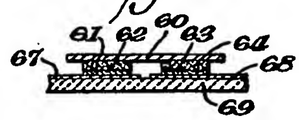


Fig.6c.

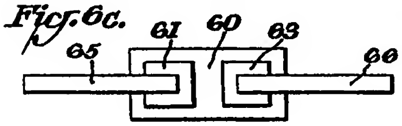


Fig.7a.

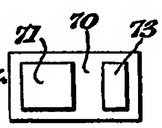


Fig.7b.

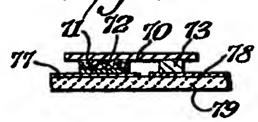


Fig.7c.

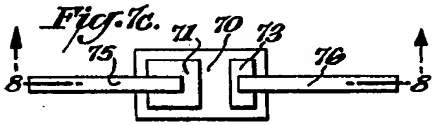


Fig.8.

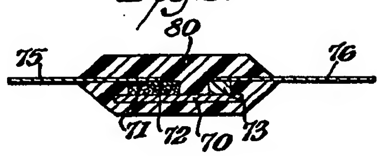


Fig. 9.

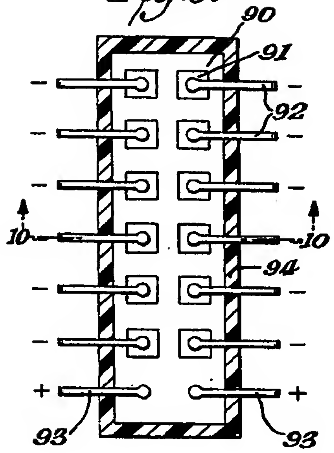
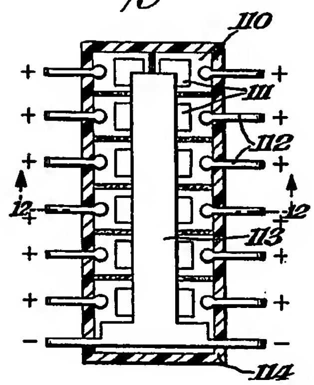


Fig. 11.



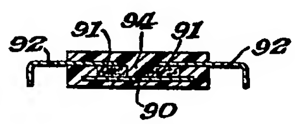


Fig. 10.

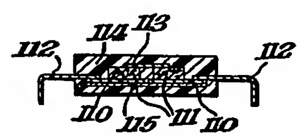


Fig. 12.